Divergence in Dialogues *

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Abstract

This work is part of a project which goal is to understand natural language by taking dialogue as a primitive notion. For this aim, the core of our theoretical framework is a logical theory of interaction, namely Ludics. *Ludics* is a logical theory developed by J.Y. Girard as an achievement of both proof theoretical and computational theoretical considerations. Above all it is a theory of interaction in the sense that interaction is ontologically the primitive element of Ludics. Ludics being a logical theory, our framework is relevant for grasping logical dimensions of language, especially for studying argumentation but also divergences in dialogue as we show in this paper. In particular complementary aspects of argumentation and divergence in dialogues are modelled in a uniform way: from logics and pragmatics to semantics and syntax. Furthermore we account for several features of dialogues directly at the formal level. Therefore, we may expect a fine-grained representation of various dialogical phenomenas. More precisely we illustrate this last point by describing how different divergences in dialogue may be distinguished in our modelling.

1 Introduction

During these last decades, dialogue has become again the subject of intensive studies. This is the case inside Logics. The relevance of the dialogical frame for Logics is well known since Aristotle and it continues to be an important ingredient for logical studies [6, 3]. The study of dialogues is also essential in argumentation theory, in which debates and controversies are consubstantial to argumentation. The study of natural language makes also use of dialogical situations for grasping various aspects of natural languages, semantical but also syntactical ones [15, 1]. In this perspective, works of J. Ginzburg are noticeable as they consist in developing directly a Theory of Dialogue (KoS, [9]). Our aim is very close to his approach as we also intend to define a theoretical framework able for studying linguistic phenomenas starting from their manifestations in dialogues. Our proposal shares with KoS numerous methodological postulates:
– Meaning should not be studied on decontextualized sentences, by adding phonetical and pragmatical modules to syntactical and semantical ones. Instead, all features have to be grasped together.
– For studying and describing a communication, it is relevant to take seriously into account its successful transmission of contents as well as its failures (*e.g.*, misunderstanding) and its repair attempts.
– Dynamics of language cannot be ignored. The meaning of an utterance is elaborated in a conversational process. The attempts for making explicit, for repairing, for updating parts of meaning have an important role.
Nevertheless, our approach has to be distinguished from KoS with respect to the theoretical

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framework on which it relies. Indeed, we place ourselves in the perspective of recent philosophical positions, as for example Pinker's claim: "Dialogue is at the origin of language" [13], or Brandom's position with his inferentialist semantics based on asking and giving reasons [2]. According to these approaches, interaction is ontologically the primitive fact of language. This is why we choose Ludics as our formal framework. *Ludics* is a logical theory developed by J.Y. Girard [10] as an achievement of both proof theoretical and computational theoretical considerations. Above all, it is a theory of interaction in the sense that interaction is ontologically its primitive concept. Preliminary works have shown the interest of this logical framework for the modelling of dialogues (*e.g.*, [11, 12, 4]). Ludics being a logical theory, our framework is relevant for grasping logical dimensions of language, especially for studying argumentation [7, 5] but also divergences in dialogue as we show in this paper. In particular complementary aspects of argumentation and divergence in dialogues are modelled in a uniform way: from logics and pragmatics to semantics and syntax. Furthermore we account for several features of dialogues directly at the formal level. Therefore, we may expect a fine-grained representation of various dialogical phenomenas. More precisely we illustrate this last point by describing how different divergences in dialogue may be distinguished in our modelling.

2 A Frame for a Dialogue Theory

2.1 A few Facts on the Theoretical Framework

Ludics is a theory of interaction: its main object is the interaction itself and its dynamics. *Designs* are the support of interaction. Interaction between designs is allowed when these designs are (at least partially) localized at the same *address* (*i.e.*, a *cut* in terms of logics). Such a situation triggers the dynamical process of interaction that abstracts the logical process of cut-elimination. We refer the reader to [10] for a thorough presentation of Ludics, we just sketch below elementary aspects.

The elementary step of an interaction is an *action* (a move in Game Semantics), which is represented as a triple: (i) a *polarity*, that is positive (resp. negative) with respect to one of two interacting designs, when the action is produced (resp. received) by this design; (ii) the *current address* of the interactive process; (iii) a finite set of *new addresses* that the action creates (positive polarity) or expects (negative polarity) and on which the interaction may continue. In addition, there is a special positive action called *daimon* and denoted by ✠ which enables to terminate an interaction.

A *base* is a finite set of addresses that localizes the design: interaction may begin on such addresses. Formally it is a sequent $\Gamma \vdash \Delta$ where Γ contains at most one address, which is said in negative position, and Δ contains a finite set of addresses, said in positive position. A *design* based on $\Gamma \vdash \Delta$ is a set of coherent alternate sequences of actions starting on the address in Γ if it exists, in Δ otherwise.

An *interaction* between two designs occurs when their bases share an address in dual position. The process of interaction is a step by step travel through dual alternate sequences of actions. This process may diverge if these two (dual) sequences yield actions which are not dual each other, it may converge when one of these two (dual) sequences yields ✠, it may also continue indefinitely.

Two modes of interaction are available: either a *closed* mode when the base contains only addresses shared by the two designs, or an *open* mode. Interaction may then be interpreted in two ways. The closed mode focuses on the process itself: it tests the possibility that interaction may go on and converge (to daimon), without paying attention to any context. The open mode

focuses on the transformation that this process induces on the context (*i.e.*, the addresses that are not shared by the interacting designs). In terms of Logics, the first case is similar to a cut-elimination between dual formulas and it enables to decompose them with respect to their structure, the second case corresponds to a *modus ponens*: from a proof of A and a proof of $A \Rightarrow B$, we get a proof of B, where B is the context. In terms of natural language and reasoning, the first case helps modelling interacting processes, *e.g.*, dialogue processes, while the second one may be used for modelling explicitation processes, *e.g.*, calculi, deductions or context updating.

2.2 A few Facts on the Model

Our model of dialogue is organized in two levels, that we may intuitively compare to the two modes of interaction in Ludics. The first level deals with *the surface of dialogues*, *i.e.*, the flow of interventions and their role inside the process. At the second level, we take into account the content of these interventions.

2.2.1 The surface of dialogues

With respect to the first level, that considers the dynamics of a dialogue, a dialogue is seen only as an alternate sequence of interventions among which we may distinguish the one which initiates the exchange and the one which eventually ends the exchange. Interventions are only considered according to (i) their role in the flow of interventions: one intervention is anchored on a previous one and opens possible continuations of the dialogue, (ii) the fact that they are produced by one locutor while they are in the same time received by the other locutor.

We interpret interventions by means of *dialogue acts*. Formally, a dialogue act is an action of Ludics anchored in an address L opening addresses $\{L_1, \ldots, L_n\}$ together with the expression e that reveals the dialogue act in the intervention: that is a quadruple $(+/-, L, \{L_1, \ldots, L_n\}, e)$. It is worth noticing that an address created by a dialogue act (with positive polarity) may represent what Ginzburg and Fernandez call a *question under discussion* (QUD) [8]. The dialogue act is the minimal unit of communication, whose role is to fuel the dynamics and determine the shape of the dialogue. At this level, the dialogue is reduced to a process. A dialogue act expresses an entitlement or a decision of the speaker, and also its acknowledgment by the addressee. In some sense, it is quite close to a speech act. However, dialogue acts are more elementary than speech acts. Let us consider, for example, the speech acts of argumentation, as presented in [7]. While the fact to argue, to ask or to negate are accounted by a single dialogue act, the concession is accounted by a sequence of two dialogue acts: the first one, denoted κ is positive with respect to the locutor who makes the concession: κ enables to precise which assertion is conceded, it is anchored on the pending address created by the assertion which is conceded; moreover, κ creates a single new address L' on which the next dialogue act is anchored. The action with address L' is then negative with respect to the same locutor. This latter dialogue act creates no new addresses, therefore pending addresses relative to the conceded utterance disappear and cannot be used in the following of the dialogue.

An intervention, or turn of speech, is a sequence of dialogue acts. From the viewpoint of the locutor who produces it, the intervention begins and ends with a positive dialogue act. When there is no divergence or rupture of the dialogue, the sequence of dual actions is recorded by the locutor who receives the intervention. A turn of speech is then twofold: producing an utterance to her interlocutor and expecting an utterance from her interlocutor.

A dialogue defines two sequences, called *paths*: each of them being the dialogue seen from the viewpoint of one locutor. Finally each path defines a design, hence a dialogue may be

considered as the trace of the interaction between two designs, one for each locutor.

This first level of modelling captures the surface of a dialogue. It is already enough to take into account important aspects of dialogues, namely the pragmatical and rethorical ones [4]. More fundamentally, this level enables to pay attention to the notion of convergence/divergence in the dialogue. Viewing the dialogue as a trace of an interaction between two designs makes explicit the fact that there are two points of view. Therefore it allows to observe the success or the failure of a communication between these two points of view, *i.e.*, the fact that the dialogue may fail or end with a drop. Dialogues may badly end because of misunderstandings, disagreements, lacks of informations ... and it is necessary to be able to represent such situations. At each step in Ludics, an interaction may continue if a negative action exists in one design that is dual to the positive action 'played' by the other design. Transposed in our modelling, a dialogue may continue without divergence provided that the current intervention produced by a locutor (a positive action) is correctly received/expected by her addressee (the dual negative action exists).

EXAMPLE **1.** *A person* **P** *conducting a survey gives to a native the following informations: "*All the Kpelle cultivate rice. Mister Smith does not cultivate rice*". The person* **P** *asks the following question to the native* **N***:*
– **P***: "*Is Mister Smith a Kpelle?*"*
– **N***: "*I do not know Mister Smith, I have never seen him.*"*
At that level, we consider only the question and its answer that we represent each by a single dialogue act:
• $(+/-, L_0, \{L_1\}, \texttt{Is Mister Smith a Kpelle?})$*: positive for the person* **P** *that produces the question, negative for the native* **N** *that may receive it.*
• $(+/-, L_1, \{L_2\}, \texttt{I do not know...})$*: positive for the native* **N** *that produces the answer, negative for the person* **P** *that should expect it.*
But the person **P** *expects a logically correct answer,* e.g.*, "no", that we denote* $(+/-, L_2, \{L_3\}, \texttt{No})$*. He plans also to receive an incorrect answer,* e.g.*, "yes" or "it may be the case", that we denote* $(+/-, L_2, \{L_4\}, \texttt{Yes})$*.*

$$\dfrac{\dfrac{\vdash L_3 \quad \vdash L_4}{L_1 \vdash}}{\vdash L_0}$$
The viewpoint of **P**

$$\dfrac{\dfrac{L_2 \vdash}{\vdash L_1}}{L_0 \vdash}$$
The viewpoint of **N**

The interaction between the two designs associated resp. to the dialogue seen from the viewpoint of **P** *and of* **N** *diverges: the design corresponding to the viewpoint of* **P** *has no negative action dual to* $(+, L_1, \{L_2\}, \texttt{I don't know...})$*. The dialogue cannot continue.*

2.2.2 A full account of dialogues

We can refine this first approach in order to take care of other dimensions of dialogue, typically phonetical, lexical, syntactical, semantical, pragmatical and dialectical ones. In particular, we set a *cognitive base* for each locutor. A cognitive base contains, roughly speaking, the various knowledges and abilities[1] used for building utterances as well as for receiving and recording them. Such a cognitive base is twofold: (1) sets of statements, that are assumed by each locutor; (2) the linguistic elements used and received during the process of dialogue. While the level of surface of dialogues makes only use of the closed mode of interaction, the management of cognitive bases, their updating and their use in the dialogue in progress make use of the open mode of interaction[2].

[1] Once again, we intend to consider all different dimensions of language, hence knowledges and abilities concern linguistic ones (phonetical, lexical, syntactical, semantical, pragmatical and dialectical ones) as well as logical or psycho-social ones.

[2] We retrieve the logical dimension of a dialogue only at this level.

Concretely, we make use of the following elements for modelling a dialogue between two protagonists A and B:
– The dialogue is a sequence of triples[3] $(C_A^i, C_B^i, [[\mathcal{D}_A, \mathcal{D}_B]]^i)$, each triple indexed by i models what is at stake in the i^{th} intervention.
– C_A^i and C_B^i are the cognitive bases of respectively locutors A and B when the i^{th} intervention occurs.
– X being one of the locutors A or B, the context C_X is managed in two parts: the set of utterances publicly assumed by X, denoted by $\mathcal{E}_X$ and a record $\mathcal{R}_X$ of the linguistic elements used for building these utterances. All these elements (utterances assumed by locutors and linguistic elements) are represented by designs. Interactions between these designs enable to account for their (de)constructions. In this paper, we do not describe the part $\mathcal{R}_X$ of linguistic elements and we only focus on the part $\mathcal{E}_X$ of commitments. Furthermore we do not describe the correspondence between an utterance, seen as a knowledge, and its logical form. Therefore, in this paper, an "utterance" is an element of $\mathcal{E}_X$.
– Designs $\mathcal{D}_A$ and $\mathcal{D}_\mathcal{B}$ are the interacting designs representing the surface of the dialogue as presented in the previous subsection. The result of the interaction at step i is noted $[[\mathcal{D}_A, \mathcal{D}_B]]^i$. This result is the state of the dialogue after the i^{th} intervention.

We illustrate these elements of modelling with the following dialogue between A and B:

Example **2.**
– *A: Who wrote to Paul?*
– *B: Pierre.*

We consider three steps in this dialogue: the first one corresponds to the question asked by A; the second one is the answer given by B. The last one is not expressed explicitly in this dialogue. Nevertheless, A may consider that the answer given by B is sufficient and ends properly the dialogue: the dialogue is convergent.

1. The first intervention is produced by A. Interpreting the surface of this dialogue, it is accounted by a unique dialogue act. This latter is positive according to A, its address is initial (the dialogue is starting), it creates just a new address on which the answer of this wh-question is expected. Finally, its phonetical manisfestation is `Who wrote to Paul?`. We just account the first part of the cognitive base of A. The set of commitments of A, denoted by $\mathcal{E}_A^1$, contains two utterances:
   - *Someone wrote to Paul.* (P_1).
   - *Someone is known by the two locutors A and B; his name is Paul* (P_2).

2. As soon as B correctly received the intervention of A, the answer given by B is taken into account by the dialogue act which is positive according to B, which is anchored on the address created by the previous dialogue act (that B correctly received). It creates a single address, the one corresponding to the information *Pierre wrote to Paul.* This information is expressed by the single word `Pierre`.

   Since B receives correctly the wh-question and answers it, we may consider not only that the utterances P_1 and P_2 are available in $\mathcal{E}_B^2$ and may be activated, but also that there are other propositions in $\mathcal{E}_B^2$: B knows who wrote to Paul, therefore $\boldsymbol{\mathcal{E}_\mathbf{B}^2} = \{P_1, P_2, P_3, P_4\}$ where P_3 corresponds to the utterance *Pierre wrote to Paul* and P_4 corresponds to the utterance *Someone is known by us (A and B), his name is Pierre.*

[3]This notion is very close to the notion of Dialogue Gameboard used by Ginzburg.

3. The third step is supposed to be expressed implicitly by A, as an acknowledgment of B's answer. Therefore, the last dialogue act is produced by A and is the daimon, which terminates the dialogue on a convergence. Finally, the set of utterances publicly assumed by A contains after this third step the proposition P_3 (the answer given by B) and also the proposition P_4 (the fact that Pierre is known by A and B). Besides these two utterances, utterances P_1 and P_2 are also present in $\mathcal{E}_A^3$.

The formal representation of the dialogue is summed up in the following tables:[4]

- Dialogue surface (seen from A's viewpoint):

Steps	Dialogue acts of A	Dialogue acts of B
1	$(+, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$	
2		$(-, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$ $(+, \lambda.wh, \{R\}, Pierre)$
3	$(-, \lambda.wh, \{R\}, Pierre)$ $(\maltese, \epsilon)$	

- Contexts (cognitive bases):

Steps	C_A	C_B
1	$\mathcal{E}_A^1 = \{P_1, P_2\}$	$\mathcal{E}_B^1 = \emptyset$
2	$\mathcal{E}_A^2 = \{P_1, P_2\}$	$\mathcal{E}_B^2 = \{P_1, P_2, P_3, P_4\}$
3	$\mathcal{E}_A^3 = \{P_1, P_2, P_3, P_4\}$	$\mathcal{E}_B^3 = \{P_1, P_2, P_3, P_4\}$

3 More on Divergence

Let us consider some alternative dialogues to the previous one given in example 2.

Example **3.**
– *A: Who wrote to Paul?*
– *B: Did Paul receive a letter?*

Example **4.**
– *A: Who wrote to Paul?*
– *B: Who is Paul?*

In both cases, the first step is formalized exactly as previously. After that step, in dialogue 3 as in dialogue 4, the locutor B does not receive as expected this starting intervention. In dialogue 3, B cannot use the knowledge P_1: *Someone wrote to Paul* for her answer since this latter is not in her cognitive base. In dialogue 4, proposition P_2: *The name of someone that we both know is Paul.* is not in $\mathcal{E}_B$. In both cases, the reaction of B is to try repairing this "miscorrespondance of contexts". Nevertheless the parallel between the two situations stops here.

- In dialogue 3, the locutor B may receive easily the intervention from A, by using the design associated to $\mathcal{P}aul$ in her cognitive base $\mathcal{E}_B^2$, and by using elementary syntactical and semantical abilities. Afterwards, she may extend her context which becomes $\mathcal{E}_B^2 = \{P_1, P_2\}$. The question *Did Paul receive a letter?*, by means of which B initiates a new

[4] ϵ is the empty production.

sub-dialogue, anchored on a new address γ, is mainly the expression that B recorded this information, new for her. The dialogue may end on a convergence, A answering or not.

Namely we have:

– Contexts in dialogue 3:

Steps	C_A	C_B
1	$\mathcal{E}_A^1 = \{P_1, P_2\}$	$\mathcal{E}_B^1 = \emptyset$
2	$\mathcal{E}_A^2 = \{P_1, P_2\}$	$\mathcal{E}_B^2 = \{P_1 P_2\}$
3	$\mathcal{E}_A^3 = \{P_1, P_2\}$	$\mathcal{E}_B^3 = \{P_1, P_2\}$

– Surface of dialogue 3:

Steps	Dialogue acts of A	Dialogue acts of B
1	$(+, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$	
2		$(-, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$ $(+, \gamma, \{Q\}, Did\ Paul\ receive\ a\ letter?)$
3	$(-, \gamma, \{Q\}, Did\ Paul\ receive\ a\ letter?)$ $(\text{✠}, (yes))$	

$$\frac{\dfrac{}{\lambda.wh \vdash}}{\vdash \lambda} \qquad \frac{\dfrac{\dfrac{}{\longrightarrow \text{✠}}}{\vdash \gamma.Q}}{\gamma \vdash} \qquad \frac{\dfrac{\gamma.Q \vdash \lambda.wh}{\vdash \lambda.wh, \gamma}}{\lambda \vdash \gamma}$$

A's viewpoint B's viewpoint

The interaction between the designs corresponding to the (surface of) dialogue seen from the viewpoints of respectively A and B converges.

- In dialogue 4, B cannot receive as expected the intervention from A. In her cognitive base, B lacks utterances P_1 and P_2 that are needed and the relative linguistic elements. Once the intervention is done by A, the base of B is provided with two new utterances: *Someone received a letter, his name is Paul.* (P_3) and B *does not know who is this Paul.* (P_4). B has to initiate a new dialogue (anchored on δ) in order to complete her cognitive base and to share with A informations present in A's cognitive base.

– Contexts in dialogue 4:

Steps	C_A	C_B
1	$\mathcal{E}_A^1 = \{P_1, P_2\}$	$\mathcal{E}_B^1 = \emptyset$
2	$\mathcal{E}_A^2 = \{P_1, P_2\}$	$\mathcal{E}_B^2 = \{P_3, P_4\}$
3	$\mathcal{E}_A^3 = \{P_1, P_2, P_4\}$	$\mathcal{E}_B^3 = \{P_3, P_4\}$

– Surface of dialogue 4:

Steps	Dialogue acts of A	Dialogue acts of B
1	$(+, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$	
2		$(-, \lambda, \{wh\}, Who\ wrote\ to\ Paul)$ $(+, \delta, \{wh\}, Who\ is\ Paul\ ?)$
3	$(-, \delta, \{wh\}, Who\ is\ Paul\ ?)$	

This situation is different from the two previous ones. An intervention of a locutor is misunderstood by her addressee. Hence the addressee needs to complete her cognitive base (knowledges and linguistic elements) in order to be able to continue the dialogue. If the dialogue stops here, it is divergent.

$$\frac{\dfrac{}{\lambda.wh \vdash}}{\vdash \lambda} \qquad \frac{\dfrac{\vdots}{\vdash \delta.wh}}{\delta \vdash} \qquad \frac{\dfrac{\delta.wh \vdash \lambda.wh}{\vdash \lambda.wh, \delta}}{\lambda \vdash \delta}$$

A's viewpoint B's viewpoint

The interaction between the designs corresponding to the (surface of) dialogue seen from the viewpoints of respectively A and B, does not converge, if it stops now.

4 Conclusion

In our theory of dialogues, elements of knowledge and ability are considered individually: a cognitive base is modelled as a set of designs, each design representing a knowledge or an ability. Such a cognitive base is the set of facts that are mobilized by each locutor during the dialogue. It enables to account ruptures, failures and repair attempts occurring in dialogues. J. Ginzburg [9] makes use of a similar approach, by using context updating as the dialogue unfolds. We may outline some of the features of our formal framework which are relevant for such a methodology.

First of all, Ludics provides us with a theoretical frame that integrates interaction as a primitive and fundamental notion. Note that the same formal process is used for interpreting all levels of communication. In particular, there are two modes of interaction in Ludics. We make use of one or the other depending on which property of dialogue has to be considered. A first aspect of dialogue is modelled as a closed interaction. It integrates the necessity of keeping communication convergent. This imperative determines the surface of dialogue. A second aspect of dialogue, modelled as an open interaction, concerns the exchange of datas between locutors, the record of new informations, the update of other ones. This dimension is accounted by cognitive bases. In some sense, these two levels provide us with a more or less fine-grained account of the interaction at work in dialogues. We may either observe the flow of interaction, or focus on what is interacting (and therefore we fix, step after step, the interacting supports).

The complementarity of these two levels is illustrated by the analysis of dialogues 3 and 4. At first sight, these dialogues seem to be formally identical, both ending on a question instead of an expected answer. However a sharper study, that our modelling enables, reveals differences. In this analysis, the two levels of our formal framework are important: the model of the surface of the dialogue enables to remark that one is divergent while the other is convergent, the model of the cognitive bases enables to explain this difference: commitments sets are not equal.

Finally, it is worth noticing that interaction, as defined in Ludics and as we use it in our framework, enables to update the cognitive bases, either from one interacting side or from the other one. Therefore instead of relying on composition, our framework relies on interaction. As Ludics is a general-purpose logical and computational framework, the same formalization may be used for dealing with linguistic aspects of utterances as we do for commitments. As a long term issue, we intend to investigate in which extent this slight shift of viewpoint might renew semantical and syntactical studies. Even if computational applications are not immediately expected, a roadmap may be sketched. To start, two questions have to be investigated. The first one concerns argumentative dialogues, the second one general dialogues. In [7], we succeeded in characterizing speech acts of argumentation as *invariant* sequences of dialogue acts. We have to complete this formalization by providing other invariant sequences of dialogue acts for argumentative markers, *e.g.* the ones studied by Winterstein [14]: *but, nevertheless, otherwise,* etc. In parallel, we intend to study dialogue ends. In particular, we should study what happens with respect to knowledge bases (a step towards such an issue is done in this paper). We should also be able to classify dialogue ends knowing that addresses that are created are closed either in the following of the dialogue or implicitly with the last interventions. In a next step we should test our formalization on a corpus of dialogues in order to refine and precise it.

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